# THE STRUCTURE OF THE SILK GLANDS OF *APANTELES GLOMERATUS* L.[1]

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*Apanteles glomeratus* is a hymenopterous social parasite of the larvae of *Pieris rapae,* the common cabbage worm. The adult females deposit at each oviposition from fifteen to thirty-five eggs in the young larvae of Pieris. The parasites on hatching, feed upon the lymph and fatty tissue of their host and grow very rapidly, becoming full grown at about the end of the larval life of the caterpillar. They then penetrate through the skin of their host and, while emerging, spin their characteristic sulphur-yellow cocoons. The silk glands, as seen in sections of the mature larvae, are enormously developed. Although the silk glands of lepidopterous and trichopterous larvae have been the objects of detailed study by Helm, Gilson, and others, very little is known concerning these glands in the Hymenoptera. As regards histological structure the only works of importance are those of Cholodkovsky, his student Pikel, and Bordas; and, excepting the latter who gives a brief discussion of these glands in the aculeate Hymenoptera, these writers have confined themselves to the study of the larvae of various Tenthredinidae. Therefore at the suggestion of Professor Riley we were led to investigate more fully the silk glands of Apanteles.

The work was carried on in the Entomological Laboratory of Cornell University. We wish to extend our thanks to Professors Comstock, Riley and MacGillivray, for their constant aid and advice.

**Anatomical Disposition of the Silk Glands.**— The silk glands of *Apanteles glomeratus* arise near the base of the labium and extend through the body cavity to the antepenultimate segment of the abdomen. In the abdominal region of mature larvae they consist of two pairs of thin-walled, much convoluted, cylindrical tubes (Pl. 1, fig. 3) which completely surround the alimentary

[1] Contributions from the Entomological Laboratory of Cornell University.

canal. Each pair of tubes unites in the first abdominal segment to form a common thoracic division. These common tubes, extending forwards with many convolutions in the thorax, turn ventrad just behind the developing head and passing on each side of the sub-oesophageal ganglion, end in short ducts. These ducts unite in the labial region to form the press which occupies more than half of the common duct.

In young larvae just hatched, and for several days later, the glands show no convolutions whatever. They lie as straight tubes, two on each side of the alimentary canal and extend caudad to the antepenultimate segment (Pl. 1, fig. 1). Moreover the structure is the same throughout their entire length, no regional differences occurring. Their walls are thick and their lumina very small. Later they become much convoluted, and their lumina are greatly distended, till in the mature larvae at time of emergence from the host, the abdominal division has practically ceased to secrete, becoming simply a reservoir for the already accumulated product.

The silk glands may be divided into two general divisions; 1. Secretory. 2. Conducting.

**The Secretory Division.**— The secreting division may be conveniently divided into two portions, abdominal and thoracic.

*The abdominal portion* comprises that part of the gland extending caudad from the point of juncture of the glandular tubes in the first abdominal segment.

In the freshly hatched and young larvae this portion consists of two pairs of straight glandular tubes, one pair situated on each side of the alimentary canal (Pl. 1, fig. 1). On each side the tubes lie directly one above the other. No difference in structure between the dorsal and ventral tubes could be detected. In cross section the gland is seen to be composed of two large cells surrounding a very small lumen (Pl. 1, fig. 9). Each cell is almost completely filled by a large unbranched nucleus. Externally lies the basement membrane (*b. m.*), a delicate structureless sheath surrounding the gland. On the inner surface lies a delicate, thin membrane, the structure of which we were unable to make out under the highest powers of the microscope. It appears as a thin, resistent, structureless membrane. Gilson, '90, has worked out in detail its struc-

ture in the larvae of *Bombyx mori.* He concludes his study by stating that the producing portion is clothed by an extremely fine resistent cuticula, in which are found spiral filaments of various thicknesses, united to one another by delicate transverse or oblique trabeculae. He does not consider that these meshes are closed by a structureless lamella but refrains from a positive statement.

As the larvae feed and grow, this portion, during the third and fourth days, commences to become convoluted; the nuclei are larger and somewhat branched; the lumen slightly increases in size. Gradually, as the cells begin to secrete actively, the glandular tubes become more and more convoluted until, at the time of emergence of the parasite from the host, they almost completely fill and greatly distend the perivisceral cavity. These changes are brought out in the longitudinal sections of young and mature larvae respectively, Pl. 1, figs. 2 and 4, and in corresponding cross sections, Pl. 2, figs. 7 and 8.

Along with the great increase in length of the glandular tubes goes a corresponding increase in size. The cells necessarily become larger, but their radial diameter diminishes. The lumen gradually becomes distended by the accumulated product, till, at the time of the spinning of the cocoon, the walls are reduced to a very thin layer (Pl. 1, fig. 11). The figures 9, 10, and 11 show the enormous increase in the size of the lumen during the very short larval life. So great is this increase that either cross or longitudinal sections of an adult larva present a very striking appearance, practically the whole body cavity being monopolized by the silk gland.

The nuclei in the glands of the young larvae are round or oval in shape and fill the greater part of the cells (Pl. 1, fig. 9). As these cells commence actively secreting the nuclei become more and more branched. The shape of the nuclei at nearly four days is shown in Pl. 3, fig. 31; during the latter part of the larval life they appear as if fragmented (Pl. 3, fig. 34). Gilson records complete fragmentation of the nuclei in certain cells of the larger part of the glandular tubes in Bombyx and Trichoptera. Marshall and Vorhies, '06, could not confirm this in the case of *Platphylax designatus* and they also deny the anastomosing of the branches.

In *Apanteles glomeratus*, owing to the thinness of the glandular walls, it was impossible to secure tangential sections which would give surface views of the nuclei. As the nuclei do not stain deeply at this stage, they are rather difficult to differentiate, although we secured fairly good results by staining with Grenacher's borax carmine, as shown in figure 34.

The cytoplasm is dense, granular, and vacuolated, especially during the latter part of the larval life when the glands are at the height of their activity (Pl. 1, figs. 10 and 12). Through the cytoplasm run trabeculae, extending in many cases from the external border to the inner margin of the cell. These trabeculae appear as fine radiating lines, but later, with the thinning of the glandular walls, they disappear.

Gilson, '90, performed some interesting experiments in order to determine the method of secretion. He ligated the entire living larvae, disposing the ligatures in two pairs, the two threads of each pair being close together. He then divided the larva into three sections by cutting between each pair of ligatures. Treating the cut surfaces with mercuric chloride and collodion he secured living isolated portions of the caterpillar, in each of which the silk glands, especially near the ligatures, continued to secrete. In such isolated portions he found vacuoles present in the cytoplasm and even in the nuclei of the silk glands. These vacuoles he considered as the silk secretion. He did not succeed in establishing whether they lay between the radiating trabeculae or not. In the case of *Apanteles glomeratus* the condition which Gilson sought to obtain by mechanical means is the normal one since none of the secreted product is used till at the time of emergence from the host. Numerous vacuoles are present in the cytoplasm, becoming most abundant during the time of the greatest glandular activity. The contents of these vacuoles remain unstained by any of the coloring agents used, but the secreted product is sometimes stained as is noted later. Whether the presence of these vacuoles in the cells is due to the retention of the secreted product in the lumina of the glands remains an open question.

*The thoracic portion* of the secretory division of the gland consists of but two secreting tubes, lying one on each side of the alimentary canal (Pl. 1, fig. 1). Each is formed by the union of the

two tubes of the abdominal division in the first abdominal segment and extends cephalad to the short duct which begins just in front of the sub-oesophageal ganglion. The thoracic portion may be divided into three well defined parts,— the 1st, or anterior thoracic; the 2nd, or middle thoracic; and the 3rd, or posterior thoracic divisions.

The 3rd, or posterior thoracic, division during the first half of larval life consists of an almost straight cylindrical tube. Later it becomes much convoluted and its walls become thinner so that in every way it markedly resembles the abdominal portion. The cytoplasm is densely granular, deeply staining, and much vacuolated, especially near the periphery of the cells (Pl. 2, figs. 14 and 16).

The 2nd, or middle thoracic division, is quite short and straight. It extends from the beginning of the second thoracic segment to the first division. The cells of this portion of the gland have a greater radial diameter than in any other part. The layer of "gres" or "gum," so prominent in the 1st division, is very thin and in some places difficult to distinguish. The cells are characterized by a faintly staining, loosely granular cytoplasm, which near the periphery of the cells, is much vacuolated (Pl. 1, figs. 19 and 20).

The 1st, or anterior thoracic division, is also short and straight. It extends from the beginning of the first thoracic segment to the duct. This portion of the gland is characterized by a thick dense layer of "gres" or "gum" adhering closely to the inner surface of the secreting cells (Pl. 1, fig. 23; pl. 3, figs. 24 and 30). The cytoplasm of these cells is dense, granular, and deeply staining, contrasting strongly with that of the middle or 2nd thoracic division as shown in Pl. 3, fig. 24.

The nuclei of these divisions differ mainly in the extent of their branching. In the 1st they are not so markedly branched as in the 2nd, and in the 3rd, or posterior division, they are yet more ramifying. The basement membrane is of the same character as in the abdominal divisions. The internal lining of the lumen is more distinct. It appears as a thin, elastic, structureless, cuticular membrane.

A fact worthy of note is the absence of the glands of Philippi.

There is no indication of a vestige of these glands, such as Gilson found in *Limnophilus rhombicus*, one of the Trichoptera.

**The Conducting Division.**— The conducting portion of the silk glands is Y-shaped, with a median stem and branches pointing caudad; each branch joins the thoracic portion on its respective side of the body. The press commences at the juncture of the two branches. The entire conducting portion is very short, being wholly confined to the labium. In cross section the branches are seen to be composed of a number of cells surrounding a small lumen (Pl. 3, fig. 25). The nuclei are oval to rounded in shape,— never branched. Posteriorly the cells are columnar and contain elongated nuclei, but anteriorly the cells become flattened (Pl. 3, fig. 30). There is thus formed an enlarged lumen at the anterior end of each branch of the conducting tube. Also by the increased radial diameter of the posterior cells the amount of "gres" or "gum" that can pass forward is regulated (Pl. 3, fig. 30).

The cuticular lining of these branches forms chitinous folds or ridges which are not perfect spirals but appear as incomplete rings. (Pl. 3, figs. 25, 29 and 30, *in*).

**The Press.**— Although the internal disposition of the silk glands was familar to the earlier anatomists, nothing was known regarding the mechanism by which the silk thread was formed and regulated until the time of Lyonet. He designated the entire labium as the "filiere," because it was the instrument which had been given to the caterpillar for spinning. He was the first to demonstrate the presence of the press with its attached pyramidal muscles, but he did not succeed in working out its structure. He concluded by supposing that this organ acted as a pump to draw up the silk from the glandular tubes and to force it to the exterior.

Dr. Azoux, '49, in his classic model of the silk worm, represents with exactness these pyramidal muscles of the press.

Helm, '76, was the next worker who added anything new regarding this organ. His figures and descriptions of its structure are not at all exact yet he arrives at correct conclusions regarding its function. He considered it to act simply as a press in the formation of the silk thread. It was not till the important works of Gilson and Blanc that the minute structure of this organ in Lepidoptera and Trichoptera was known and its functions clearly defined.

Berlese, '06, denies the presence of a press in the silk glands of the larvae of Hymenoptera, Diptera, and Coleoptera. He figures a sagittal section of the head of the larva of *Xylotoma rosae* but does not represent muscles as present in the region of the conducting tube. On the other hand the presence of a press in hymenopterous larvae has been recorded by Eckstein, '90, in *Lyda pratensis,* and Pikel, '96, in *Lophyrus pini.* Both of these workers figure this organ as present but give no definite details regarding its structure. Pikel states that in structure it is similar to that described by Tichomirow for *Bombyx mori.*

*Structure of the Press.*— In the case of *Apanteles glomeratus* the press is highly developed. It commences at the union of the two conducting tubes in the region of the labium and occupies more than half of the common duct. Dorsally the press is concave, traversed by a longitudinal furrow into which pass the dorsal pair of muscles as shown in cross and longitudinal sections in Pl. 3, figs. 27, 29 and 30. The ventral surface is convex (Figs. 27 and 30); its cells are somewhat elongated and secrete the thicker chitinous layer of the common duct. The dorsal muscles consist of numerous fibers which are attached directly to the chitin along the longitudinal median furrow as shown in figures 27 and 29. Emerging from this furrow the muscles separate laterally and, passing dorsocaudad, are inserted on the chitinous layer of the floor of the buccal cavity (Fig. 27). The ventral muscles are each composed of several fibers. They are located as shown in cross section in Fig. 27. They are inserted on opposite sides of the press and, passing almost directly ventrad, have their origin on the ventral body wall, being attached directly to the chitin.

The lumen of the press, as seen in cross section (Fig. 27), is horseshoe-like in form. When the muscles are relaxed this lumen is practically closed, thus preventing the further egress of the thread. The lumen is lined with a thick chitinous layer which is more strongly developed on the ventral side. This chitinous layer is directly continuous with that of the ducts. In Fig. 27 the dorsal portion of this layer appears thick, but this is due to the obliquity of the section which was necessary in order to show the muscles in one section.

In very young larvae the press is not yet developed. The dorsal median furrow and the attached muscles cannot be distinguished

and it is not till about three days after hatching that the furrow and attached muscles become clearly differentiated. Being functional for such a short time its complete development does not take place till late in the larval life. It is not till shortly before emerging from its host that the press becomes completely developed as it is not necessary that it should be fitted for spinning during the entire lifetime of the larvae but only for the very short time occupied in the building of its cocoon.

In structure the press differs from that described for Lepidoptera in that the lateral pair of muscles is not present, and from that of the Trichoptera in that each dorsal muscle is single and not divided into two distinct bundles as figured by Gilson.

*Functions of the Press.*— The functions of the press in the Lepidoptera have been carefully worked out by Gilson and Blanc and there is no doubt that the functions of this structure in the Hymenoptera are similar. These functions may be summed up as follows,—

1. The press modifies and regulates the form and diameter of the two threads.

2. It regulates the layer of "gres" or "gum" which surrounds these threads.

3. By the relaxation of the muscles the chitinous walls, on account of their elasticity, contract and hold the thread immovable as in a vise.

Gilson attributes to the press another function, that of forcing the thread to the exterior when by accident or voluntarily the thread is broken in the spinneret. This is denied by Blanc who holds that the contraction of the muscles of the press, distending its lumen to the fullest extent, together with the pressure upon the contents of the gland due to the elasticity of its walls, and the general muscular contractions of the body, serve to force the thread to the exterior when broken in the spinneret or even in the conducting tube.

In the case of *Apanteles glomeratus* we do not think the press possesses the latter function attributed to it by Gilson, inasmuch as the pressure exerted by the elastic walls of the abdominal portion and the general contractions of the somatic muscles along with that of the muscles of the press, seem to us a more correct explana-

tion of how the thread is first forced to the exterior and also how it is extruded when broken.

It is not necessary for us to describe the mechanism of spinning as that has been fully done by Blanc and Gilson for the Lepidoptera and their descriptions serve equally well for the hymenopterous larvae. The method of spinning the cocoon in *Apanteles glomeratus* has been well described and figured by Reaumur.

**The Spinneret.**— From the press a short chitinous tube leads to the spinneret (*sp.* Figs. 28, 29 and 30). The lumen of this tube gradually widens as it approaches the exterior (Figs. 29 and 30). The entire length of the common duct is .875 mm., of which the press occupies .4 mm. The spinneret is situated just beneath the buccal cavity and consists of two small chitinous projections directed cephalo-dorsad (Fig. 28, *sp.*).

**Functions of the Different Parts of the Silk Gland.**—*Abdominal Division.* As previously pointed out the abdominal division of the silk glands consists, in the young larvae, of two pairs of straight cylindrical tubes lying on each side of the alimentary canal. As the larvae grow these parts become active, their lumina become gradually distended with the secreted product till, in the mature forms, the glandular walls are so thin as to warrant the assertion that they have practically ceased to secrete and are merely reservoirs for the accumulated product.

The question as to whether the "gres" or "gum" is secreted by one particular region of the gland and the silk by another is still unsettled. Gilson in 1890 and again in 1894 came to the conclusion that both are secreted throughout the gland; and that the silk, properly speaking, is the result of a selection effected in the layer of secreted product lying next the internal face of the cells. Whether this process of selection is a chemical phenomenon or merely a physical separation, he does not attempt to decide. From a study of several series of sections he concludes that the outer or cortical layer of the secretion is granular in appearance and has special affinity for coloring agents. Neither of these conclusions is absolute since he did not find them to hold true in all cases.

Blanc, '89, p. 24, states that "The silk secreted in the posterior part of the gland is discharged continuously into the reservoir and, on its arrival there, it is surrounded by a new material which is

formed in this region. This substance is the 'gres.'" He considers (pp. 27–28) the "gres" as nothing more than the peripheral layer of silk oxidized in the reservoir, the oxidation being due to the presence of a large number of tracheae in this region.

In the abdominal portion of the silk glands of *Apanteles glomeratus* the secretion appears as a hyaline, faintly staining product. Fixation in Flemming's solution and staining with iron haematoxylin gives it a greenish color, the peripheral portion often being black. In the anterior part of the abdominal portion the peripheral layer is always stained black. Safranin colors the entire secretion salmon color, the peripheral layer always more deeply, especially in the anterior part of the abdominal portion. Mayer's acid haemalum and eosin do not color it at all.

Judging from the staining properties of the secretion the conclusion that there is a differentiation between the peripheral layer and the central column appears justified. Whether this peripheral layer is the "gres" or not is a question which we do not pretend to answer.

*Thoracic Division.* This portion of the gland remains actively secreting much longer than the abdominal division. The characteristic appearance of an actively secreting portion is shown in Pl. 2, fig. 16. The peripheral area often appears less deeply stained and numerous vacuoles are always present.

The character of the secretion in the posterior thoracic division appears similar to that of the abdominal portion except that the peripheral layer has a greater radial diameter and that vacuoles are generally more numerous. It also takes the same characteristic colorations.

The anterior and middle thoracic portions secrete a somewhat different product. The character of the cells of the middle portion would indicate that such is the case here at least. Fixation in Fleming's solution and staining with iron haematoxylin gives to this division a very characteristic appearance. The cytoplasm is filled with rather large rounded black granules thus easily differentiating this portion from the other two thoracic divisions. The nature and function of these granules we were unable to determine. In similarly treated glands many identical black granules are seen near the internal surface of the cells just within the internal membrane. These granules are present in all parts of the gland except the first thoracic division (Pl. 1, figs. 10 and 12).

The dense secretion covering the inner surface of the 1st thoracic portion indicates that this is its own peculiar product and not that of the following division. This secretion appears closely striate in a radial manner. Acid haemalum and eosin do not color it; iron haematoxylin, safranin, and Grenacher's borax carmine stain it but slightly. The central column of silk, however, is more densely stained with iron haematoxylin and safranin.

As the glands of Philippi are not present it is only speculation to suppose that the secretion of the second thoracic portion may be of a nature similar to that of these glands in the Lepidoptera. The function of the product of the glands of Philippi is not definitely known. Nearly all workers differ in their conclusions in regard to this question. The conclusion of Blanc, '91, and Berlese, '06, based upon the experiments of Robinet, '39, seems the most logical. These authors consider its function that of lubricating the thread which is to pass through the press.

The fact that the thread, in *Apanteles glomeratus*, begins to take on its definite form at the posterior end of the 1st thoracic portion might indicate that the secretion of the 2nd division had a coagulating effect upon the silk and "gres."

## Summary

1. The silk glands of *Apanteles glomeratus* differ from those in the Lepidoptera and Trichoptera in that there are four tubes in the abdominal region. Their histological structure is similar to that of Lepidoptera and Trichoptera but differs markedly from that described for the tenthredinid larvae.

2. In immature larvae the epithelial cells of the whole producing region are actively secreting. Numerous vacuoles are present in these secreting cells, especially near the periphery.

3. In glands fixed in Flemming's solution and stained with iron haematoxylin there are present, near the inner margin of the secreting cells, many black rounded granules. These are very abundant in the 2nd thoracic portion and absent in the 1st thoracic portion. Their nature and function we were unable to determine.

4. In mature larvae the abdominal division becomes greatly

distended and nearly fills the entire body cavity. It is probable that this portion now acts merely as a reservoir and that its cells have ceased secreting.

5. The glands of Philippi are absent and it is probable that the second thoracic portion performs the functions of these glands.

6. The press is well developed. It differs from that of the Lepidoptera in that the lateral pair of muscles is absent, and from that of the Trichoptera in that there is a single pair of dorsal muscles rather than two distinct pairs.

7. The product of the gland is a double thread as in the Lepidoptera and Trichoptera.

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## EXPLANATION OF THE FIGURES.

Fig. 1, pl. 1.— Optical section of a young larva shortly after hatching, showing the arrangement of the silk glands. (*s. g.*). ×

Fig. 2, pl. 1.— Longitudinal section of a young larva about six days old. The silk glands have not yet become much convoluted. × 37.5.

Fig. 3, pl. 1.— Mature larva showing the enormous increase in the size of the silk glands (*s. g.*). × 12.5.

Fig. 4, pl. 1.— Longitudinal section of a mature larva. × 12.5.

Fig. 5, pl. 2.— Cross section of a young larva (about one day old) in the thoracic region. × 130.

Fig. 6, pl. 2.— Cross section of a mature larva in the thoracic region. × 37.5.

Fig. 7, pl. 2.— Cross section of a young larva (shortly after hatching) in the abdominal region. × 130.

Fig. 8, pl. 2.— Cross section of a mature larva in the abdominal region. × 37.5.

Fig. 9, pl. 1.— Cross section of the posterior end of one of the tubes of the abdominal division of the silk glands. From a larva just hatched. × 267.5.

Fig. 10, pl. 1.— Cross section of the same portion of the gland as in Fig. 9 but at a later period of the larval life. × 267.5.

Fig. 11, pl. 1.— Cross section of the same portion as shown in Figs. 9 and 10 but from a mature larva. × 267.5.

Fig. 12, pl. 1.— Section of a portion of the glandular wall of the abdominal division showing presence of vacuoles (v) and radiating trabeculae in the cytoplasm. × 260.

Figs. 13, 14, and 15, pl. 2.— Cross sections of the third thoracic portion at different periods of the larval life; Fig. 13 shortly after hatching, Fig. 14 at a later period, Fig. 15 from a mature larva. × 267 5.

Fig. 16, pl. 2.— Section of a portion of the 3rd thoracic division showing numerous vacuoles (*v*) near the periphery of the cells. From an immature larva. × 260.

Fig. 17, pl. 2.— Section of portion of the 3rd thoracic division in a mature larva, showing the great thinning of the glandular walls. × 260.

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Fig. 19, pl. 1.— Cross section of the 2nd thoracic portion from a nearly mature larva. × 260.

Fig. 20, pl. 1.— Section of a portion of the 2nd thoracic portion, showing numerous vacuoles (*v*) near the periphery of the cells. × 260.

Fig. 21, pl. 1.— Union of the 2nd and 3rd thoracic divisions. × 260.

Fig. 22, pl. 1.— Surface view of the cells of the 2nd thoracic portion. × 260.

Fig. 23, pl. 1.— Cross section of the 1st thoracic division immediately behind the conducting portion. × 260.

Fig. 24, pl. 3.— Longitudinal section of the point of union of the 1st and 2nd thoracic portions. × 267.5.

Fig. 25, pl. 3.— Cross section of one of the conducting branches. × 260.

Fig. 26, pl. 3.— Cross section of the common duct just behind the press. × 260.

Fig. 27, pl. 3.— Cross section of the press, showing the muscular attachment; *d. m.*, dorsal muscles; *v. m.*, ventral muscles. × 260.

Fig. 28, pl. 3.— Longitudinal section of the press, showing the position of the dorsal and ventral muscles, *s. t.*, silk thread passing through the press to the spinneret. × 260.

Fig. 29, pl. 3.— Same as Fig. 28, but showing the attachment of the muscles directly to the chitin of the conducting tube. × 267.5.

Fig. 30, pl. 3.— Longitudinal section of the press, of one of the conducting branches, and of the beginning of the 1st thoracic portion. *a.*, point of union with the conducting branch of the opposite side. × 267.5.

Fig. 31, pl. 3.— Surface view of a cell and its nucleus, from the abdominal portion. From a larva nearly four days old. × 260.

Fig. 32, pl. 3.— Surface view of a cell and its nucleus, from the anterior end of the 2nd thoracic portion of a mature larva. × 260.

Fig. 33, pl. 3.— Surface view of a cell and its branching nucleus, from the posterior portion of the 3rd thoracic division of a mature larva. × 260.

Fig. 34, pl. 3.— Portion of a cell and its nucleus, from the abdominal division of the glands of a nearly mature larva. × 260.

*List of Abbreviations*

*a. c.*, alimentary canal.
*b. c.*, buccal cavity.
*b. m.*, basement membrane.
*br.*, brain.
*c. d.*, common conducting tube.
*ch.*, chitin.
*co. l.*, cortical layer.
*d. m.*, dorsal muscle.
*e. d.*, conducting tube.
*f. b.*, fat body.
*gr.*, "gres" or "gum."
*ht.*, heart.
*in.*, intima.
*int.*, intestine.
*hyp.*, hypodermis.
*l.*, lumen.
*m.*, muscle.
*m. t.*, Malpighian tube.
*n. c.*, nerve cord.
*nu.*, nucleus.
*ov.*, ovary.
*pr.*, press.
*s.*, silk.
*s. g.*, silk gland.
*sp.*, spinneret.
*s. t.*, silk thread.
*tr.*, trachea.
*v.*, vacuole.
*v. m.*, ventral muscle.
*1st. t.*, 1st or anterior thoracic.
*2nd. t.*, 2nd or middle thoracic.
*3rd. t.*, 3rd or posterior thoracic.

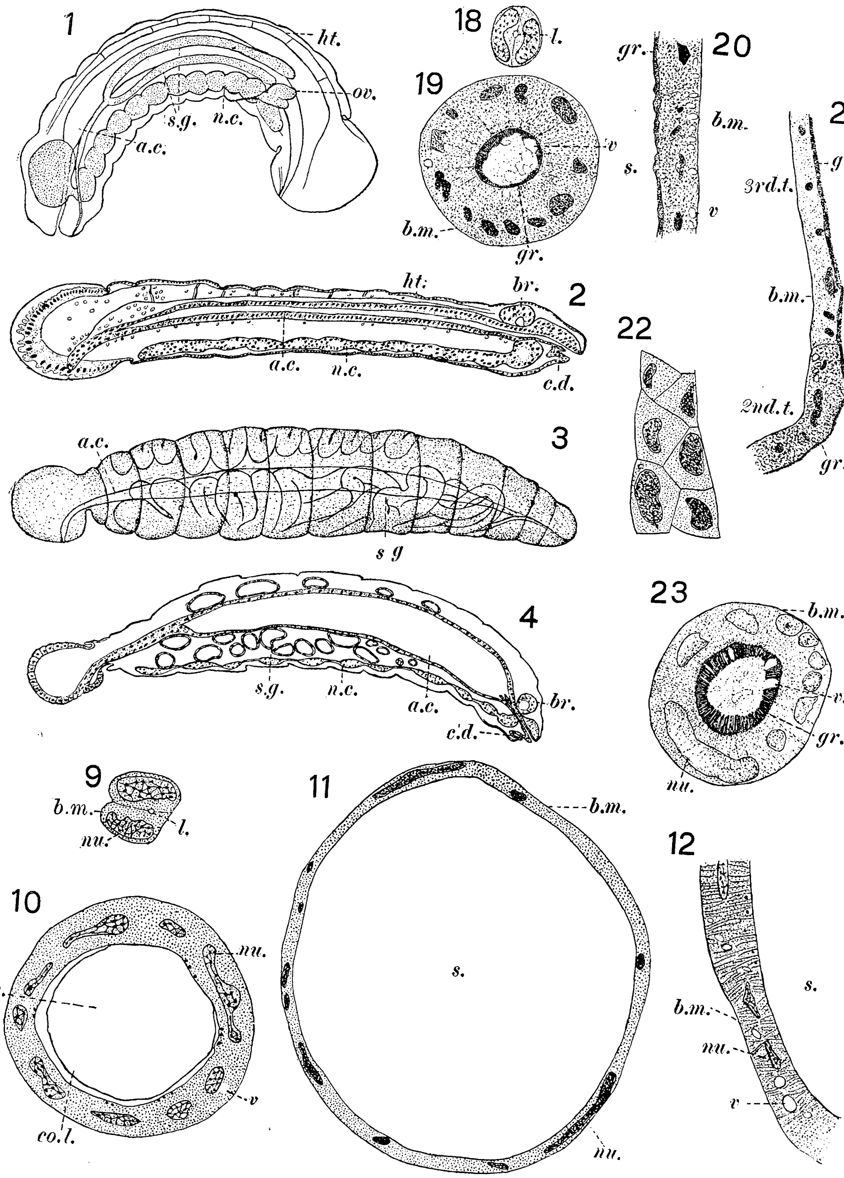
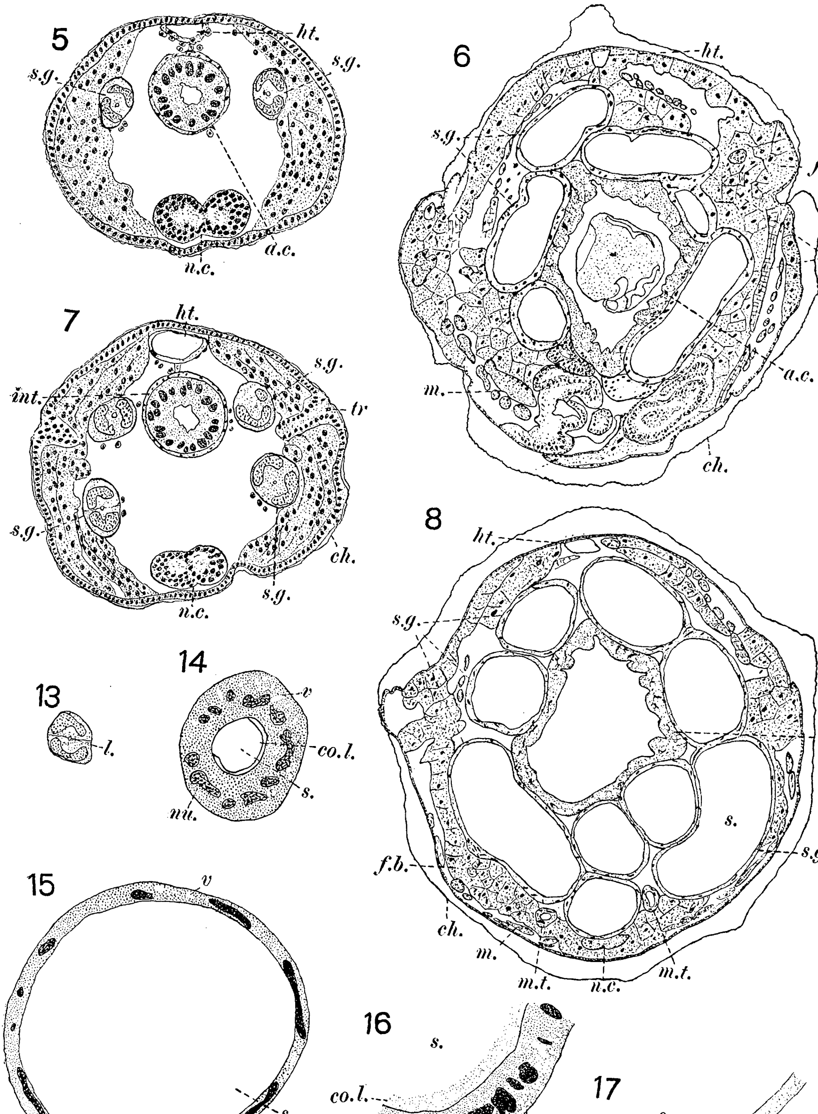

1
ht.
ov.
s.g.
n.c.
a.c.
18
l.
19
v
b.m.
gr.
20
gr.
b.m.
s.
v
21
gr.
3rd.t.
b.m.
2nd.t.
gr.
2
ht.
br.
a.c.
n.c.
c.d.
22
3
a.c.
s g
4
s.g.
n.c.
a.c.
br.
c.d.
23
b.m.
v.
gr.
nu.
9
b.m.
l.
nu.
11
b.m.
s.
nu.
12
s.
b.m.
nu.
v
10
nu.
s.
v
co.l.

PLATE 1



5
ht.
s.g.
s.g.
a.c.
n.c.
6
ht.
s.g.
f.b.
s.g.
a.c.
m.
ch.
7
ht.
s.g.
int.
tr
s.g.
ch.
s.g.
n.c.
8
ht.
s.g.
int.
s.
s.g.
f.b.
ch.
m.
m.t.
n.c.
m.t.
13
l.
14
v
co.l.
s.
nu.
15
v
s.
co.l.
16
s.
co.l.
b.m.
v
17
s.
b.m.


PLATE 2

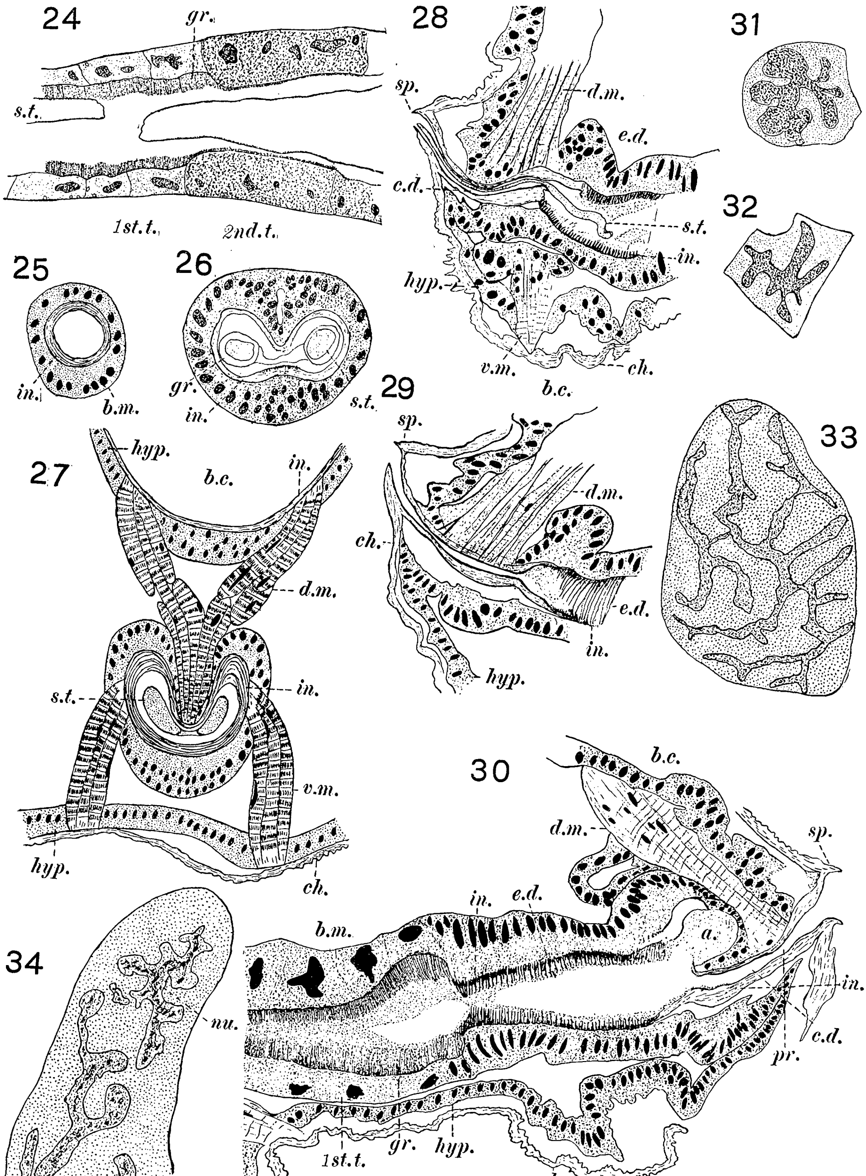

24
gr.
s.t.
1st.t.
2nd.t.
25
in.
b.m.
26
gr.
in.
s.t.
27
hyp.
b.c.
in.
d.m.
s.t.
in.
v.m.
hyp.
ch.
28
sp.
d.m.
e.d.
c.d.
s.t.
in.
hyp.
v.m.
b.c.
ch.
29
sp.
d.m.
ch.
e.d.
in.
hyp.
30
b.c.
d.m.
sp.
in.
e.d.
b.m.
a.
in.
c.d.
pr.
1st.t.
gr.
hyp.
ch.
31
32
33
34
nu.

PLATE 3